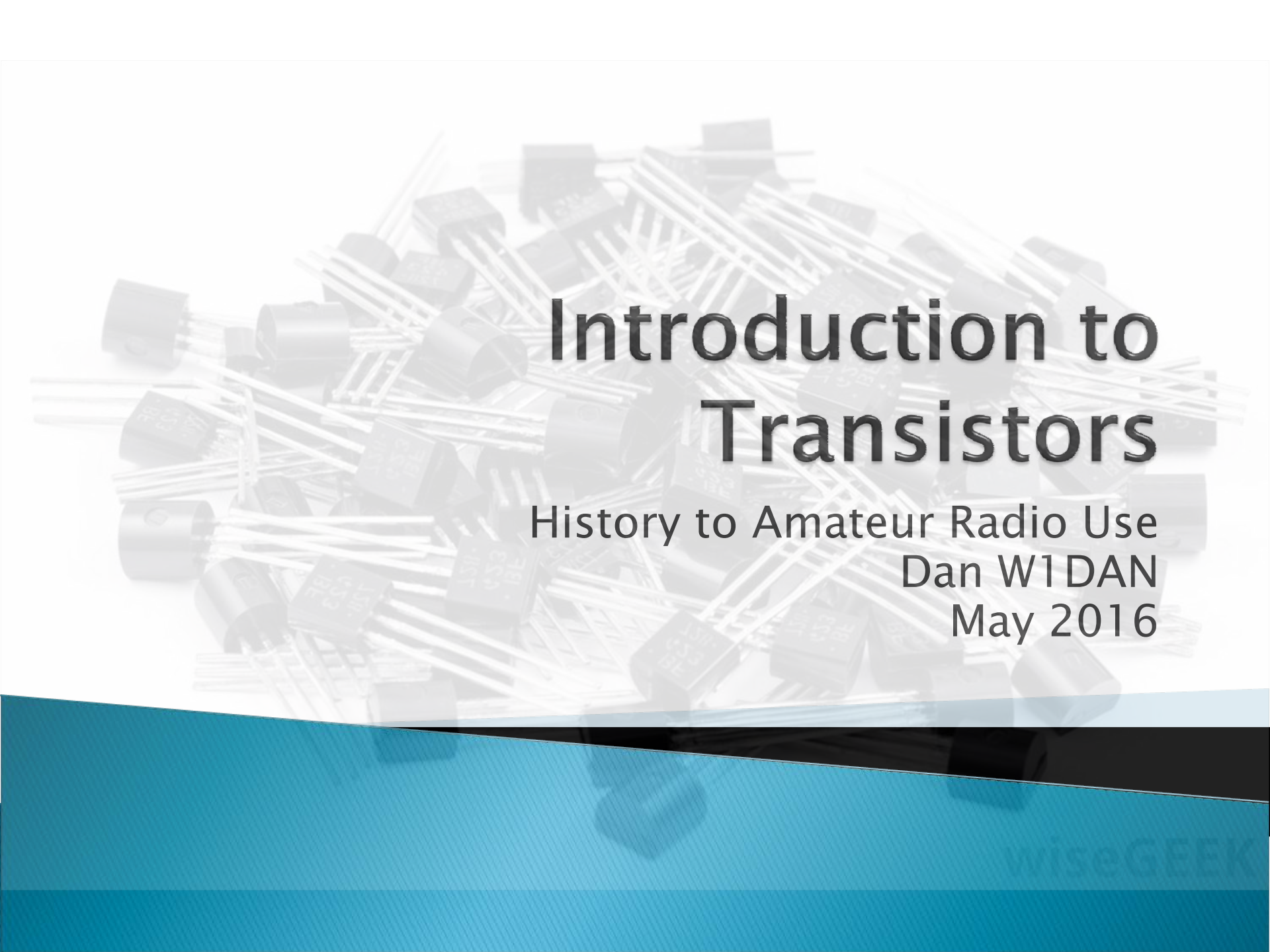


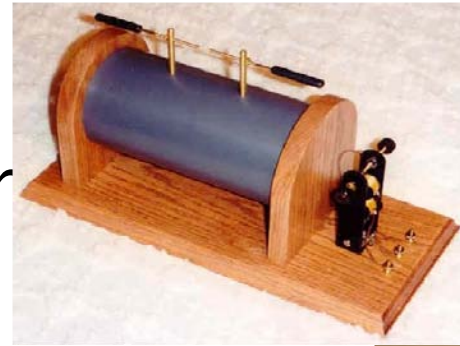


Introduction to Transistors

History to Amateur Radio Use
Dan W1DAN
May 2016

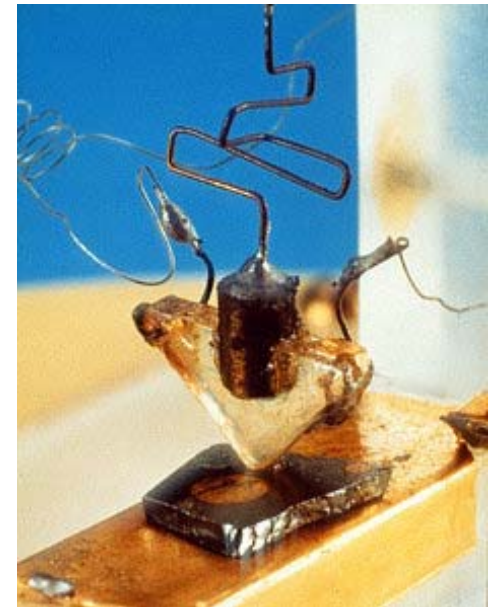
Before transistors:

- ▶ Spark-gap
- ▶ Cat's Whiskers detector
- ▶ Germanium diode
- ▶ Vacuum tube diode
- ▶ ...(up to now, no gain)
- ▶ Vacuum tube triode (deforest Audion): first gain capability and a new world of radio and audio opens



Transistor Beginnings

- ▶ Earlier inventions by Lilienfeld and Heil do not get noticed.
- ▶ Bell Labs developed the “PNP point-contact germanium transistor” in December of 1947. This transistor had gain of 18 up to 10Kc (audio range).....



The gang who did it!

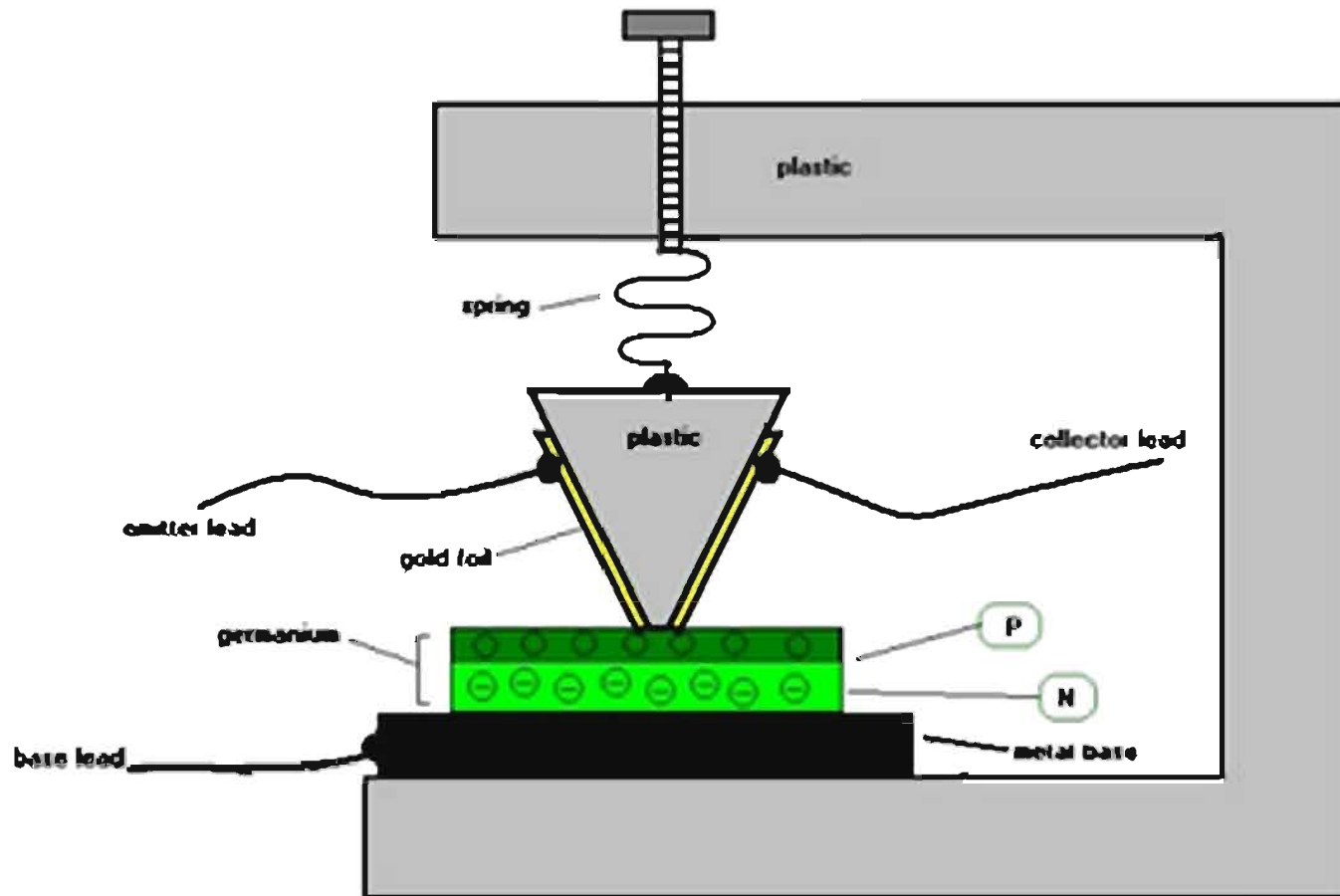


John Bardeen, William Shockley and Walter Brattain at Bell Labs, 1948.

The Bell Labs transistor

- ▶ Point-contact device, like a germanium (a carbon-like metalloid) diode, but with an added Base junction.
- ▶ The base connection is below the germanium. The triangle with gold leaf has the Emitter and Collector leads. The point touches the germanium (the “point contact”) to form the transistor.

Find the point to contact....



Transistor Progress



- ▶ 1950 Shockley invented the Bipolar Junction Transistor.
- ▶ First Transistor production line started in October 1951.
- ▶ Silicone transistors were developed in 1954 at Bell and TI. More consistent and stable, and now used for most transistors.
- ▶ The first transistor radio was the Regency TR1 designed in part in 1954. Cost \$49.95 (about \$361 today).

Regency TR-1

- ▶ Rickard Koch, project engineer and later VP of Regency and father of WARS member Don NT1L received patent 2,892,931 for the design.



Don NT1L notes....

- ▶ The original design from TI was a 6 transistor radio (1 mixer, 1 LO, 2 IF, 1 detector and 1 audio). The Regency division of I.D.E.A (Industrial Design Engineering Assoc.) concluded that they could sell the radio if it were priced at \$49.95 for the 1954 Christmas market, but had to reduce the cost of the radio. In those days, the most expensive parts were the transistors; so, they concluded that they needed to remove two of them to make the price point.
- ▶ Number one was the detector (replaced with a diode which was relatively cheaper). Number two was combining the local oscillator and the mixer into a one-transistor converter stage. This brought the count down to 4 transistors and one diode.
- ▶ Most of the problems with making this radio was not the transistors, but finding correspondingly small components that would fit in the case (e.g. electrolytic and tuning capacitors). For the most part, in those days, nobody needed parts that small.
- ▶ Apparently it didn't get rave reviews on performance (compared with tube models – no surprise), but when I compared it to a Japanese 8 transistor radio made in 1964, it performed much better. During development, only three people at I.D.E.A knew about the project: Ed Tudor, president, Richard Koch, project engineer, and Evelyn Koch (his wife), purchasing dept.

Regency TR-1 schematic

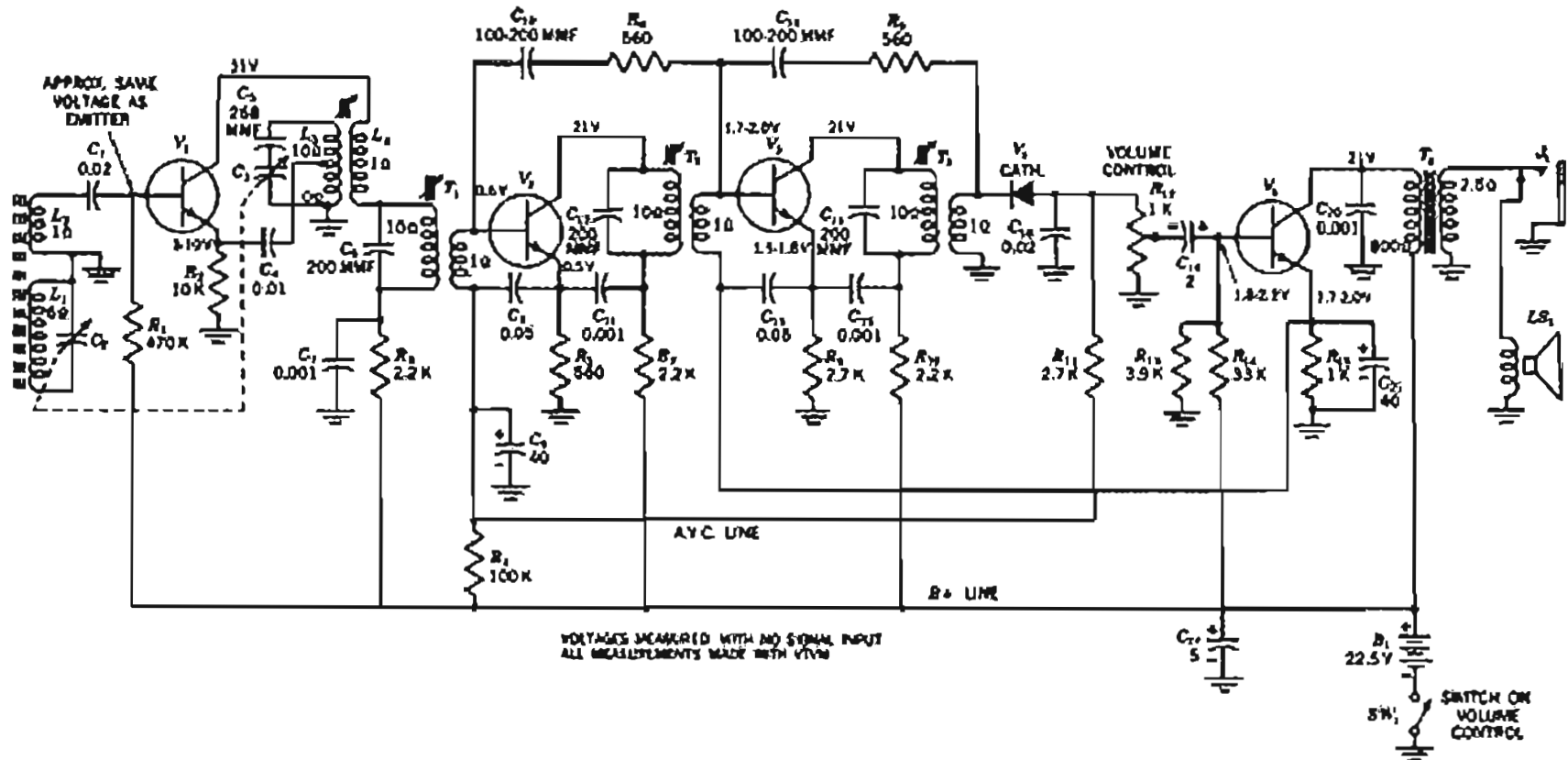


FIG. 3. The schematic diagram of the Regency model TR-1 receiver (Courtesy Howard W. Sams & Co., Inc.)

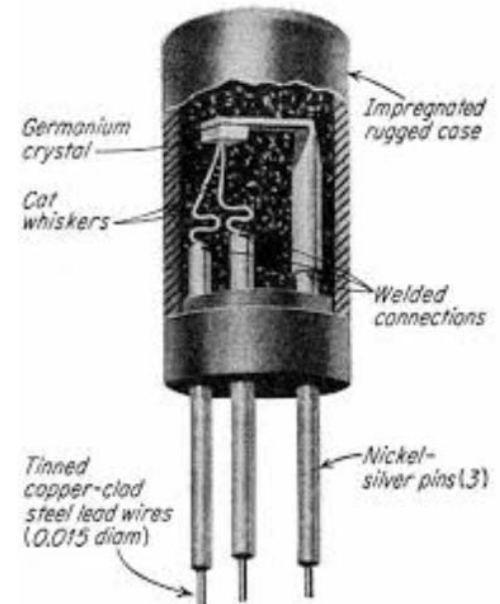
Transistor Pro's and Con's

▶ Pro's:

- ▶ More reliable than tubes
- ▶ No warm-up
- ▶ High-efficiency
- ▶ Small size
- ▶ Exceeds performance of tube gear

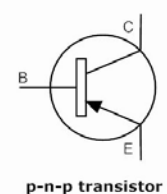
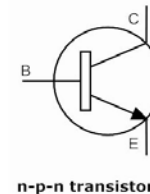
▶ Cons:

- ▶ Instant failure if values exceeded
- ▶ Susceptible to static discharge and nuclear EMP
- ▶ Most are now made in SMT packages, more difficult for experimenters

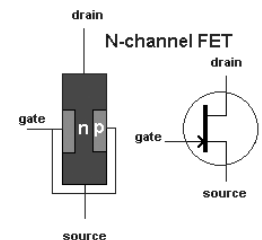


Main Types of Transistors

- ▶ Main transitory types in use today:
- ▶ Bipolar Junction Transistor (controls current):
- ▶ PNP (“Pointing iN Polarity”)
- ▶ NPN (“Not Pointing In”)

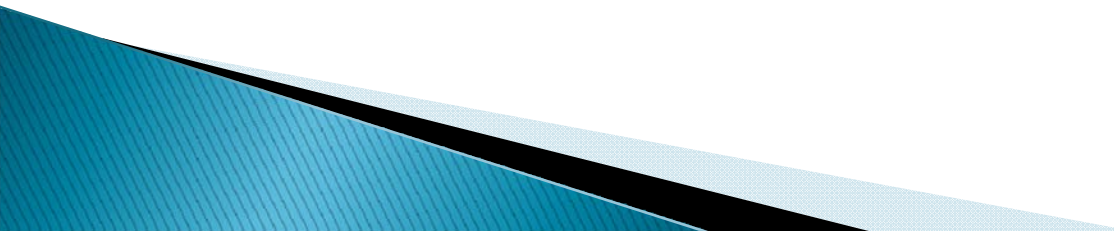


- ▶ Field Effect Transistor (like a tube)
- ▶ MOSFET
- ▶ IGBT
- ▶ LDMOS (ham linears, FM and TV transmitters)
- ▶ Germanium (old)

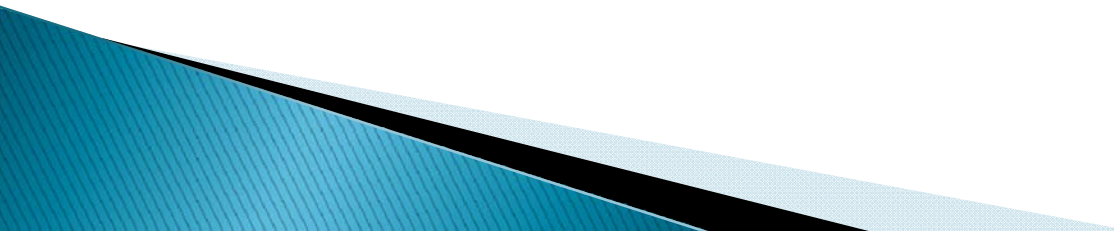


Function:

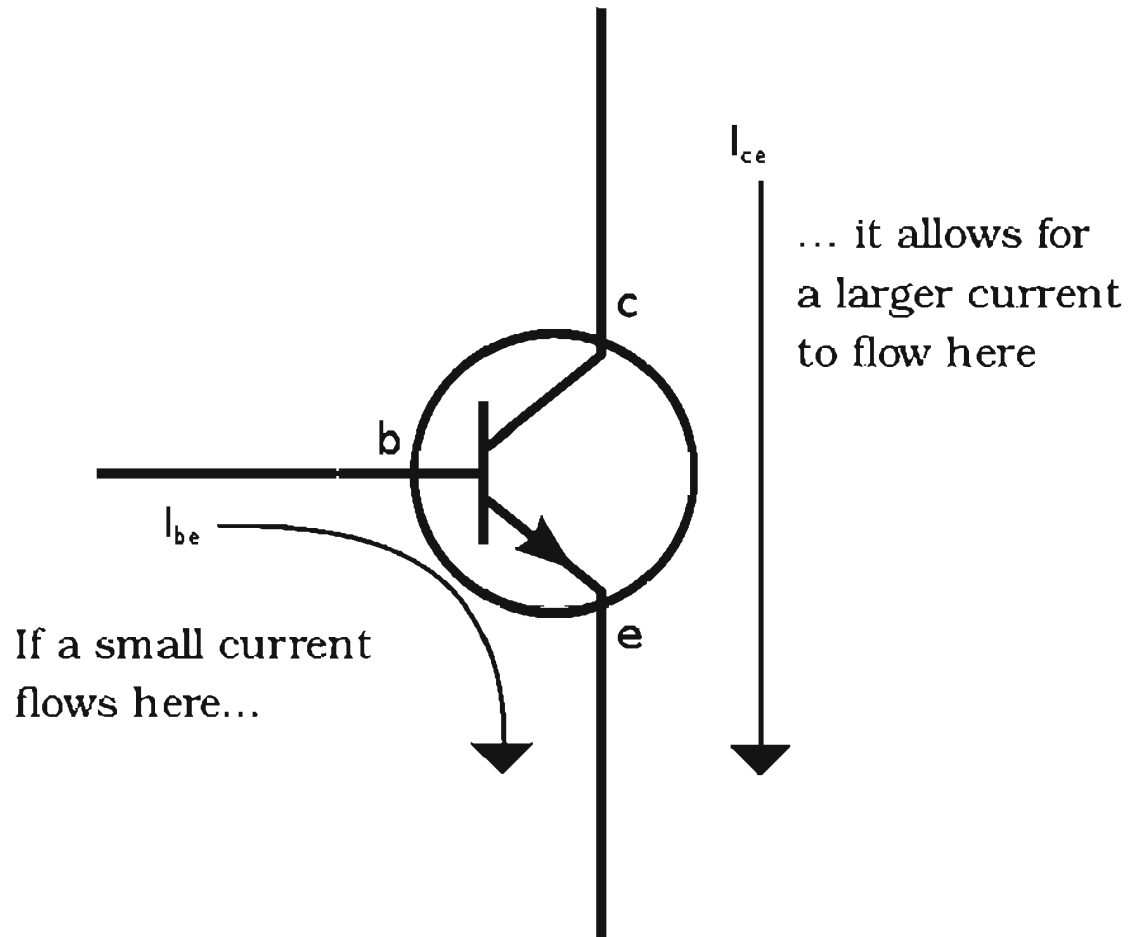
- ▶ Small signal (mic amp, RF front end, instrumentation)
 - ▶ Switching (FET)
 - ▶ HF (front end and power)
 - ▶ Phototransistors (often used in opto-ispolators, night-lights)
 - ▶ Unijunction (electronic switch to feed an SCR)

 - ▶ RF power transistors:
 - ▶ MRF150 common in HF transceivers
 - ▶ MRF151G FET transistor
- 

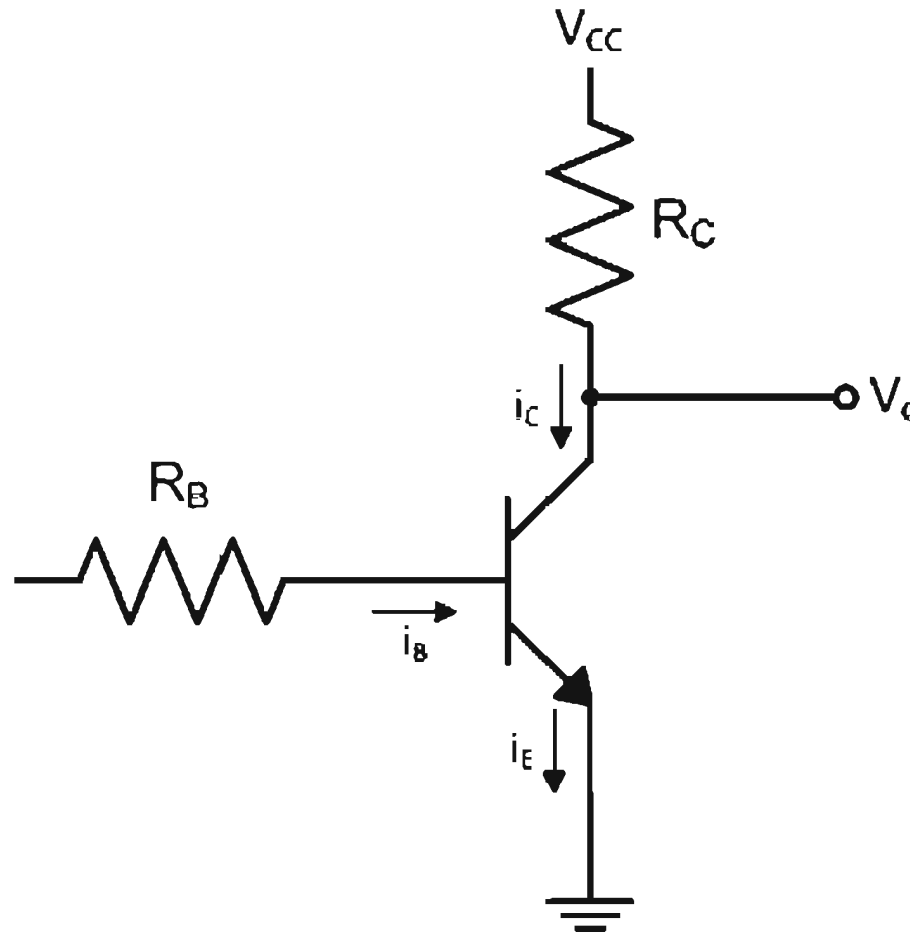
How a BJT transits!

- ▶ Current gain–makes a small current into a larger one.
 - ▶ Signal is fed into Base.
 - ▶ DC voltage is fed into Collector.
 - ▶ Output usually taken from Collector.
 - ▶ Emitter is close to ground.
 - ▶ Current converted to voltage by resistors
- 

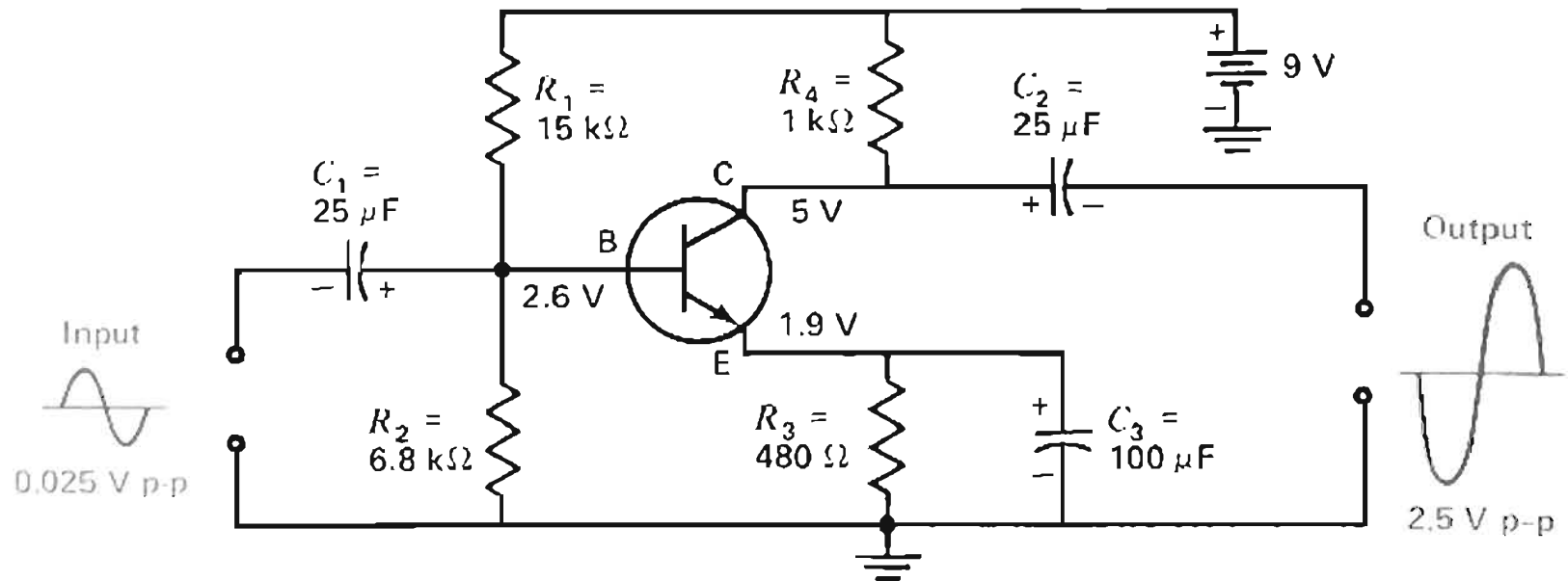
Current flow



Resistors create voltage gain



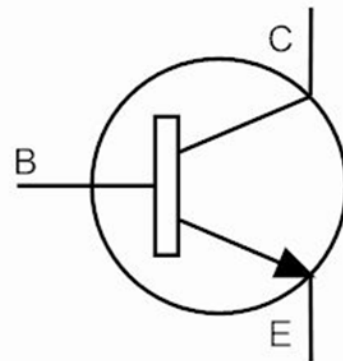
A real NPN Audio Amplifier



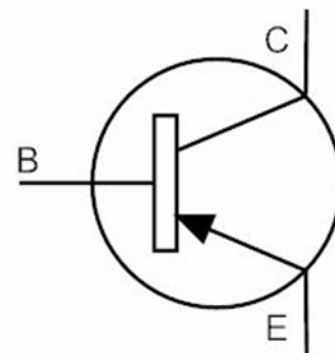
NPN and PNP BJT's...

NPN: Sinks current. i.e. current flows from Emitter to Collector

PNP: Sources current. i.e. current flows from Collector to Emitter

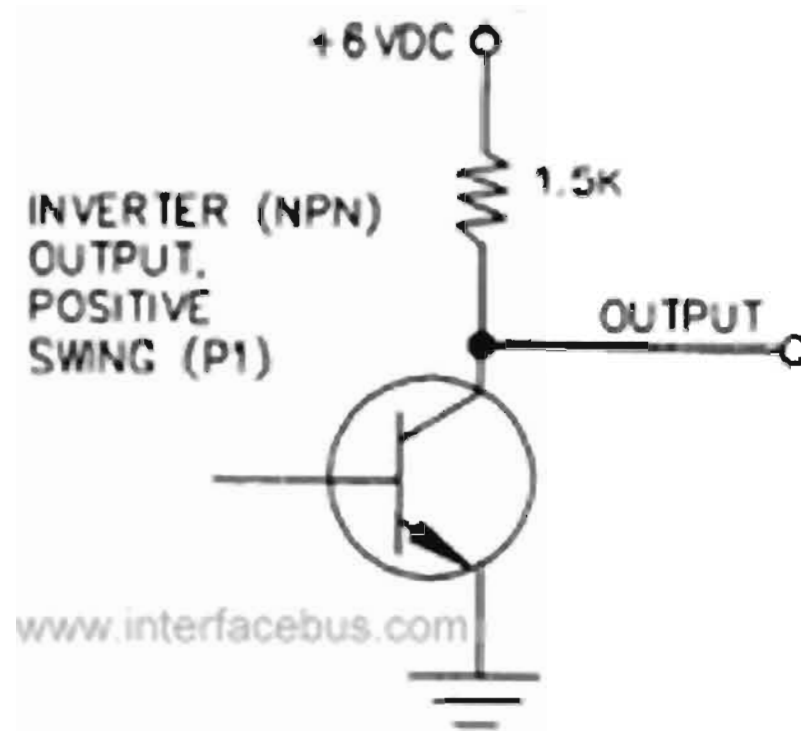


n-p-n transistor

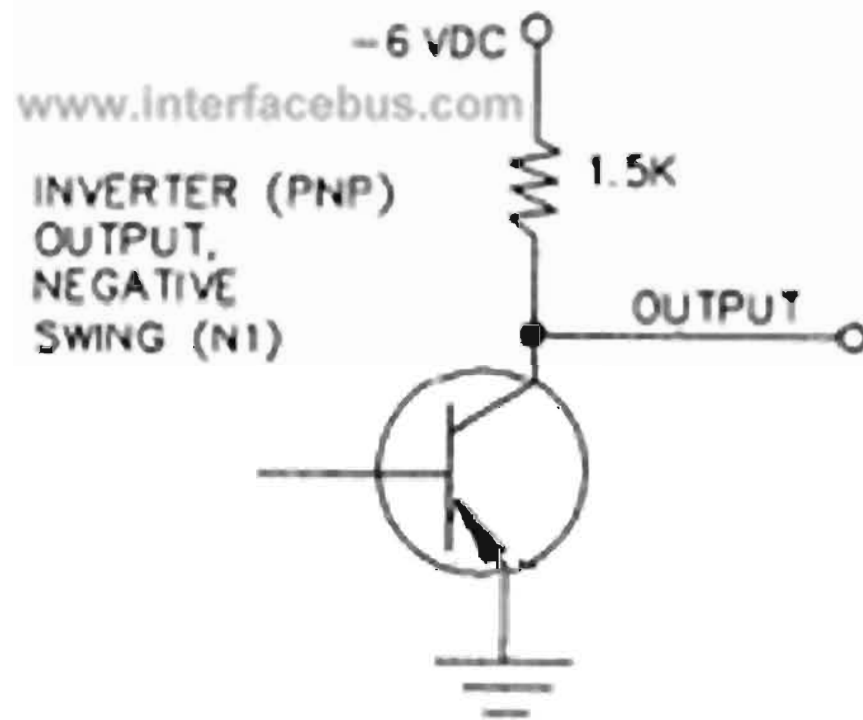


p-n-p transistor

Basic NPN amp using 2N2222

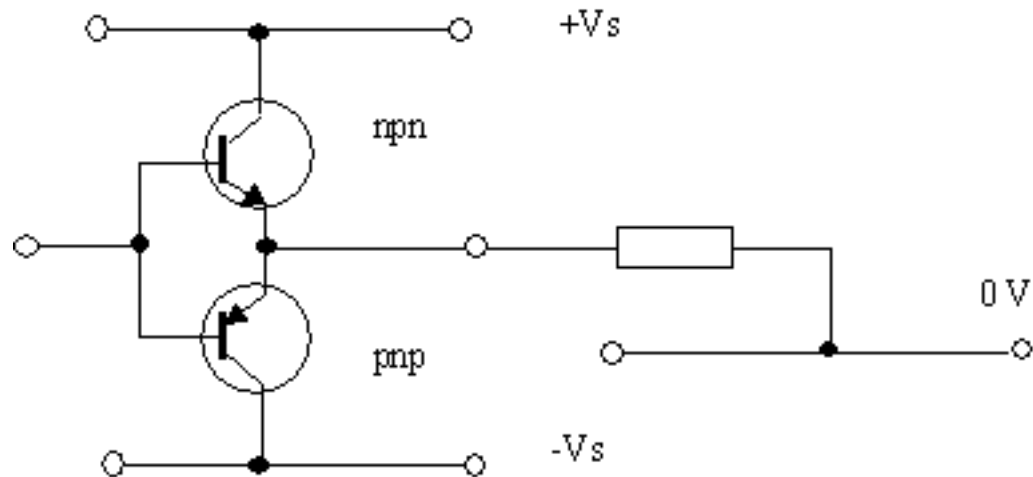


Basic PNP amp using 2N3904



Complementary output

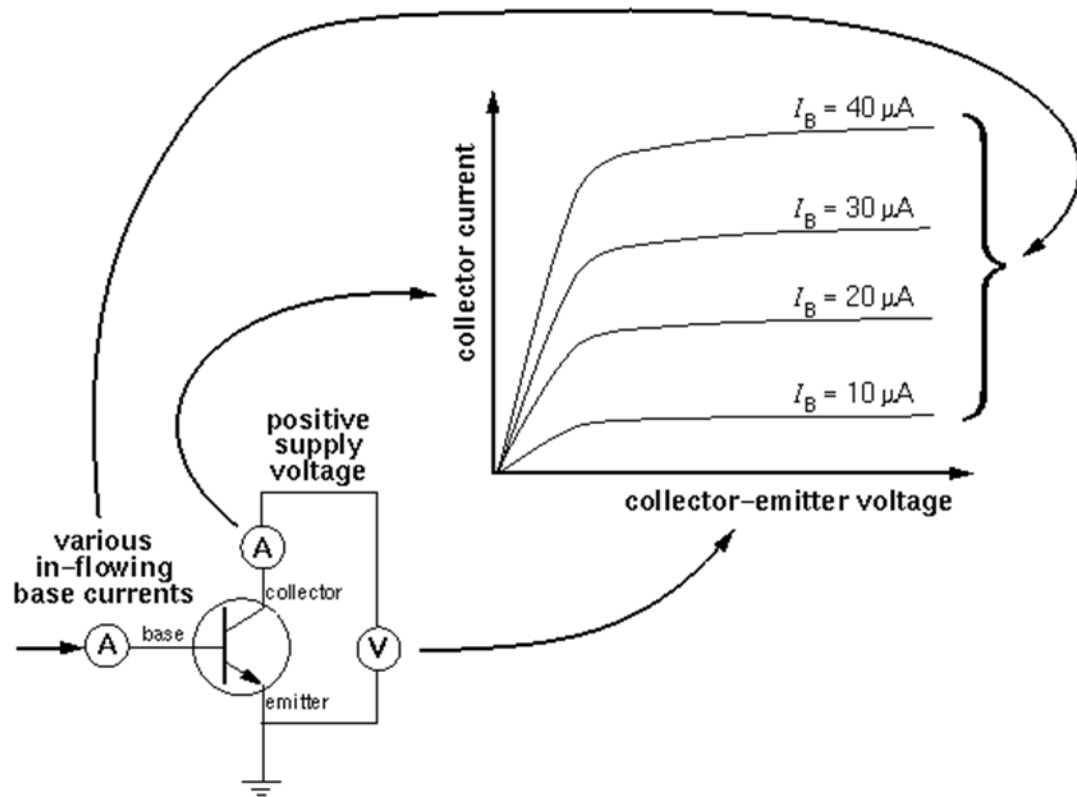
- ▶ Dual supply rails and complimentary transistors allow 0V DC output. Used in many hi-fi power amp output stages



A 2N3904 “characteristic curve”

Each transistor model has its own curve

The Base input current controls the Emitter to Collector current and voltage

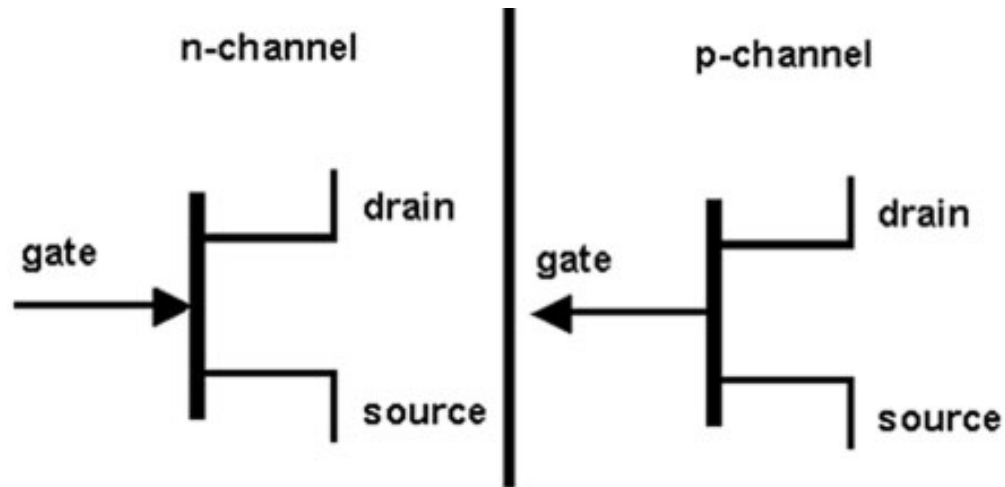


The Field Effect Transistor

- ▶ Closest to a tube.
 - ▶ Gate is insulated from the junction and creates an electric field to control the junction.
 - ▶ The Gate It is very high impedance and easy to drive (except for RF).
 - ▶ Negative temperature coefficient prevents thermal runaway
 - ▶ Easier to bias
 - ▶ Like a BJT, can be used in its linear area or as a switch
 - ▶ Can control massive power (kilowatts) with 5 volts and a few ma fed to the Gate
- 

I like the FET.....

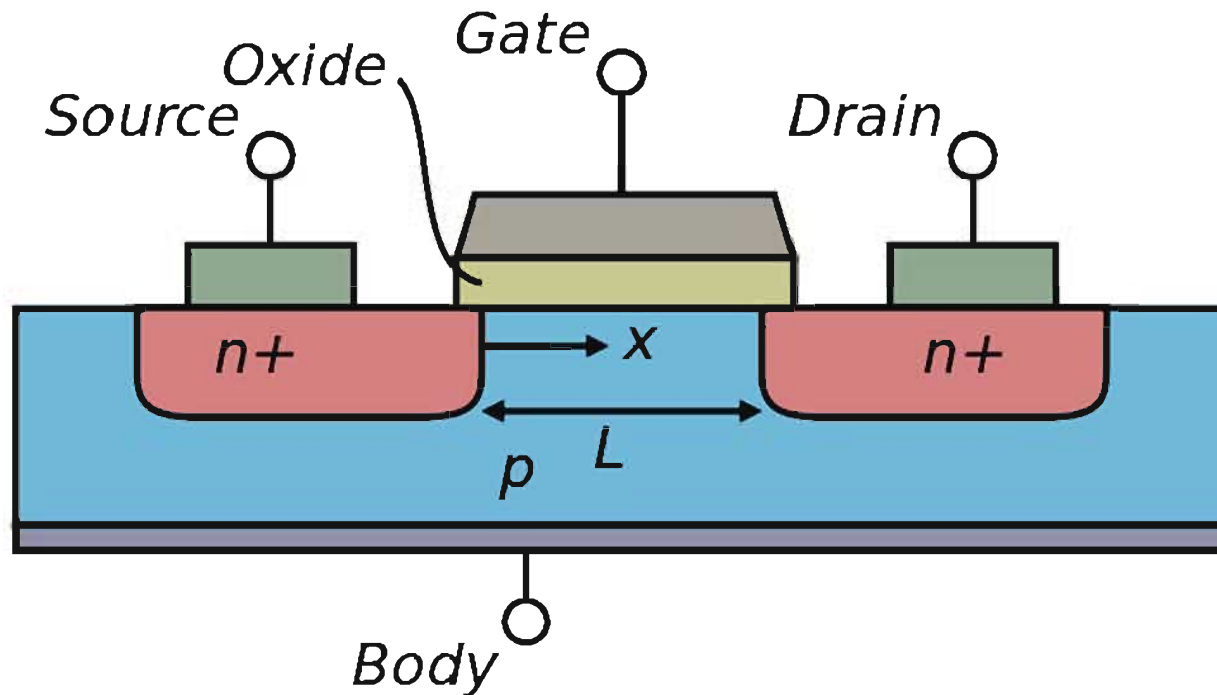
- ▶ N and P channel FETs



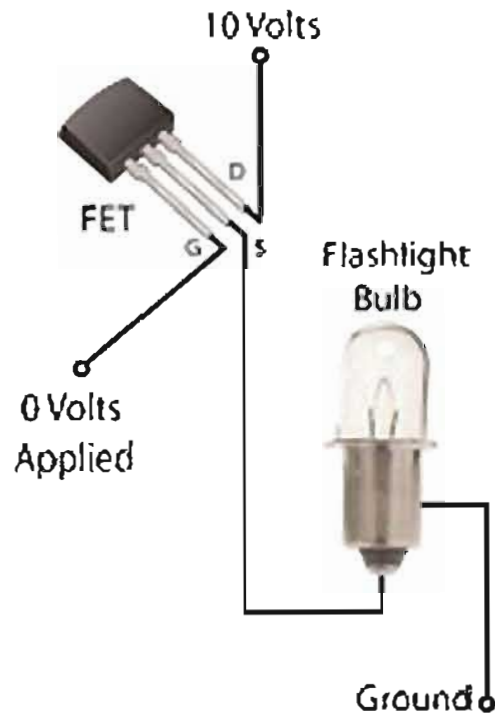
FET

Field-Effect Transistor

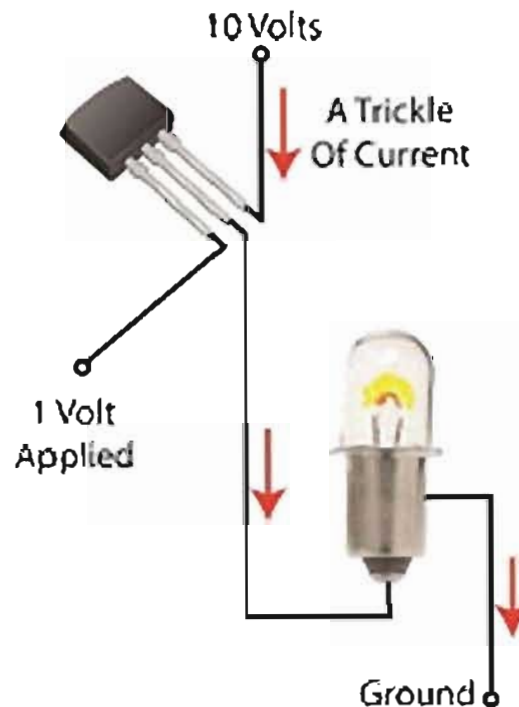
Side View of a MOSFET



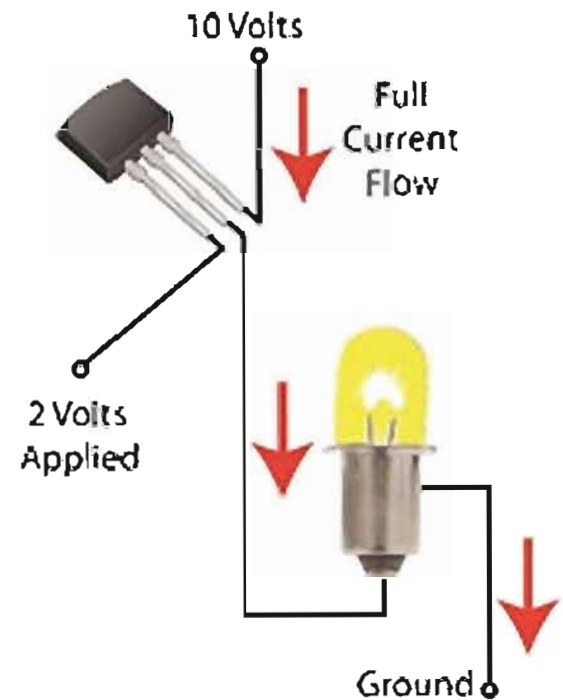
Basic FET Operation



The Bulb Does Not Light

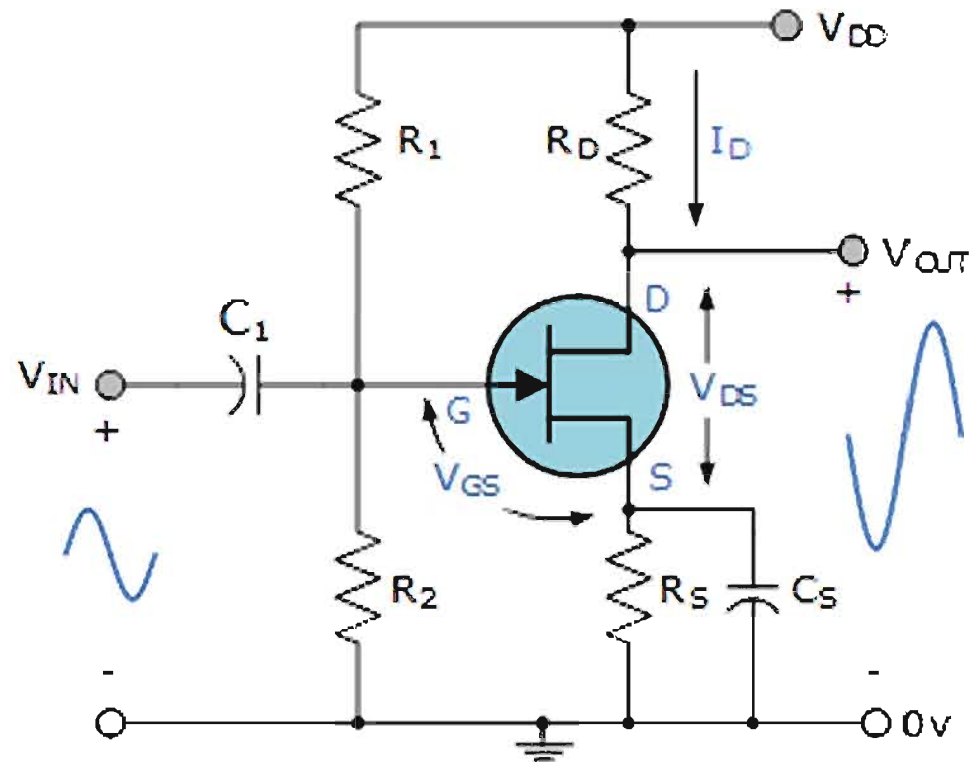


The Bulb Glows Dimly



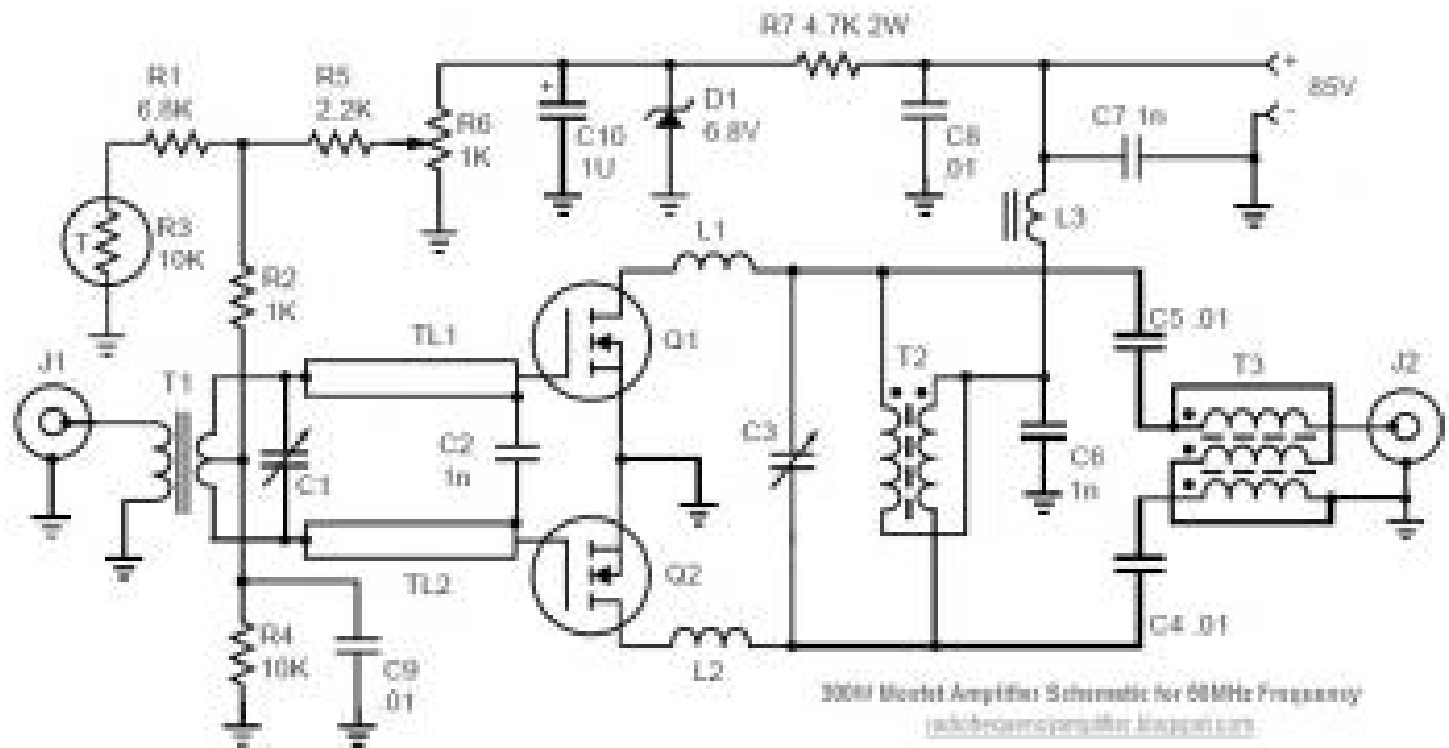
The Bulb Glows Brightly

FET amplifier

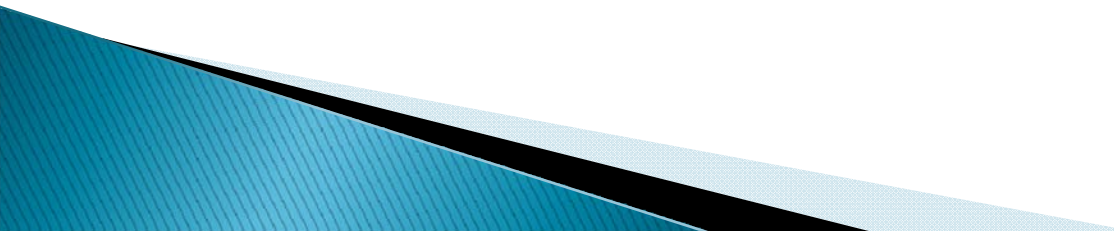


FET RF power amp

- Push-Pull 6m 300 watt amp



Manufacturers

- ▶ TI
 - ▶ Motorola
 - ▶ ON Semiconductor
 - ▶ Linear Integrated Systems
 - ▶ NTE
 - ▶ NXP
 - ▶ MACOM
 - ▶ (do not buy from foreign sellers on eBay, as many are poor counterfeits that will not perform)
- 

Transistors in Ham Radio

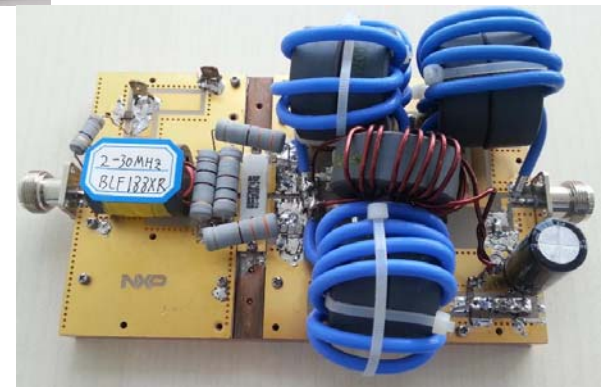
- ▶ Receiver front-ends often use dual-gate MOSFETS (40673, 3SK73, etc)–higher gain than tubes
- ▶ Receiver mixers use JFETS (J310)
- ▶ Oscillators can use a JFET (MPF102)
- ▶ Audio and low level RF can use bipolar (2N3904, 2N2906)
- ▶ RF transmitter driver transistor can be 2N3773, 2N5109
- ▶ RF PA's often use MRF150s
- ▶ Linear amplifiers can use newer LDMOS–FET BLF188XR. 1400w peak or 700w clean.

BLF1 88XR

- ▶ 700w RMS clean or 1,400 peak.
- ▶ One unit has two power transistors for push-pull operation
- ▶ Juma PA1000:



- ▶ Or homebrew (W6KAN)



Today's semiconductors

- ▶ High-performance (high-power RF, commuter rail power, etc), High-Density. IC's: op-amps, CPU's, DSP's, memory
- ▶ Gaan:



- ▶ IGBT:

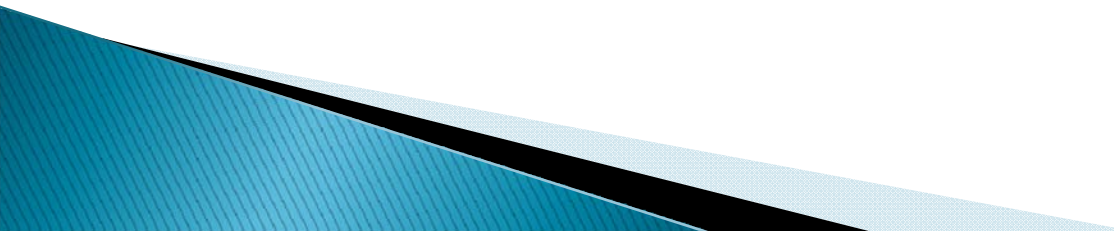


Fun experimenting

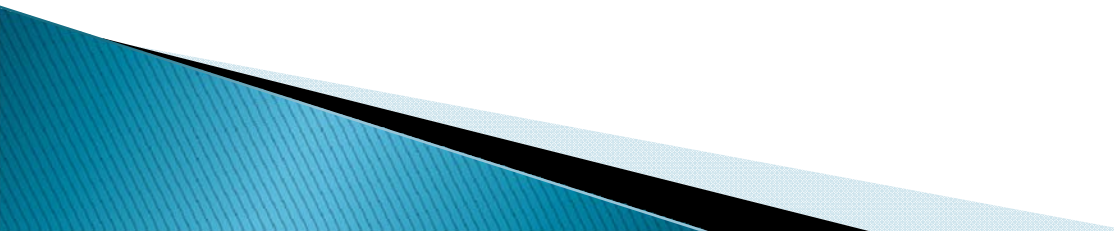
- ▶ Radio Shack 50-in-1 Science Fair kit (Dan learned as a kid)



Dan's transistor fun

- ▶ I have built with....
 - ▶ Receiver circuits: 40673, MPF102, 2N2904, 2N3906
 - ▶ Transmitter: Class E PDM. IRF450, FQA11N90
 - ▶ Regulator: 2N3055
 - ▶ Audio: FET's....
 - ▶ and tubes!
- 

YOU can play...

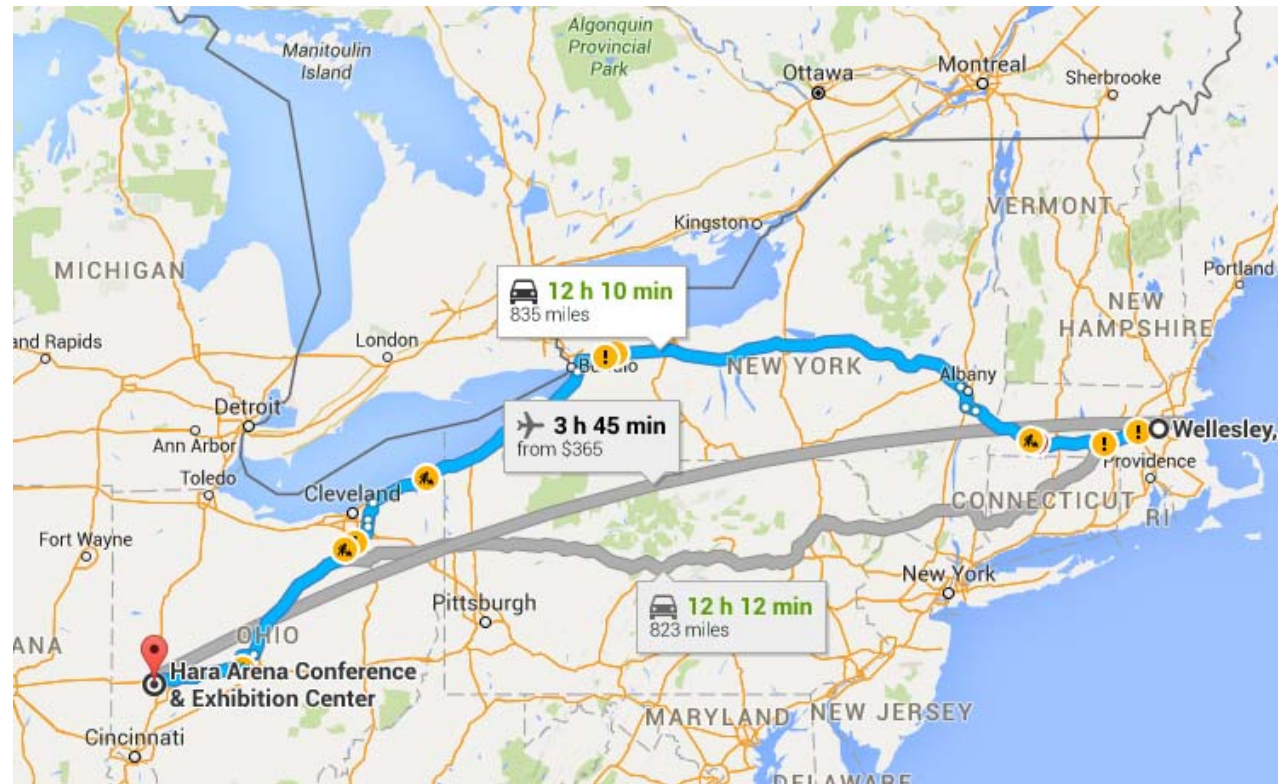
- ▶ With the following devices in simple circuits:
 - ▶ 2N3904, 2N3906, MPF102 mic amp or RF preamp
 - ▶ IRF510 for a QRP linear, or to switch a relay
 - ▶ Or whatever transistor you prefer
 - ▶ Look at QRP circuits for ideas
- 

References

- ▶ https://en.wikipedia.org/wiki/History_of_the_transistor
- ▶ <http://www.interfacebus.com/FETs.html>
- ▶ <http://pe2bz.philpem.me.uk/Parts-Active/Transistor/RF%20Power%20Transistor.htm>
- ▶ <http://www.arrl.org/files/file/QST%2520Binaries/QS0209Campbell.pdf>
- ▶ <https://www.youtube.com/watch?v=xvrjIjw3OSU>
- ▶ <https://sites.google.com/site/transistorhistory/Home/us-semiconductor-manufacturers/raytheon-part-one-2>
- ▶ <http://www.krl.com/US2892931A.pdf>
- ▶ <http://www.mequonsteve.com/regency/>
- ▶ <http://www.w6kan.com/littleboy.html>

Where to find Transistors...

- ▶ Dayton!
- ▶ Look for WA3ITR mobile at <http://aprs.fi/>



Tracking Dan & CB to Dayton

- ▶ In web browser: www.apsi.fi (no .com,.net,.org)
- ▶ Before entering callsign,
 - Show last drop down : click on 24 hrs
 - Trail tail length drop down : click on 24 hrs
- ▶ Track call–sign : WA3ITR
- ▶ And click “Search” button

Sample APRS.FI map of Boston

The screenshot displays the APRS.FI website interface. The main map shows a portion of Boston, including areas like Waltham and Newton. A search results overlay is visible, showing the following information:

Search results for wa3itr
Found 1 targets:

callsign	age	comment
WA3ITR-9	2h26m	

Buttons for 'Show selected' are present above and below the table.

The right sidebar contains several sections:

- aprs.fi - Login**: A message stating 'wa3itr was not found in the location database.'
- Miniature Atomic Clock**: A small clock widget.
- Track callsign: Clear**: A search bar with 'wa3itr' entered.
- Show last:** A dropdown menu set to '3 hours'.
- Track tail length:** A dropdown menu set to '1 hour'.
- Other views:** A list of links including Station info, Raw packets, Status packets, APRS/CWOP weather, Telemetry, Messages, Bulletin board, Prefix browsing, Google Earth KML, Data export tool, and Preferences - My account.
- Information:** A list of links including Stations currently moving, FAQ, Blog, Discussion group, Linking to aprs.fi, AIS sites, Service status, Database statistics, Advertising on aprs.fi, Technical details, API, Change log, Planned changes, Credits and thanks, Terms Of Service, and iPhone/iPad APRS.

The bottom of the page shows a download bar with two files: P1060098 (1).JPG and P1060098.JPG. A 'Show all downloads...' button is also visible.

Thanks!

- ▶ Tubes are fun, transistors are too!
(images borrowed from the Internet)

- ▶ 73,
- ▶ W1DAN
- ▶ May 17, 2016

